THE REPAIR AND REBUILDING OF THE LARVAL CASE OF PLATYPHYLAX DESIGNATUS WALK. (PHRYGANID).

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The larvæ of *Platyphylax designatus*[1] are found abundantly in a group of springs in the vicinity of Madison, and, being easily obtained at any time during the year, have been collected for work in the laboratory. Experimenting with a few larvæ which we kept in small aquaria, we noticed that those which had been removed from their cases constructed new ones and also that injuries to the cases, by removal of some part, were generally repaired in a short time by the larvæ. This led us to carry on a number of experiments to determine how far injured shells would be repaired by the larvæ, and, if certain parts of the cases were more frequently and readily rebuilt than others.

The springs in which these Phryganid larvæ live remain open all the year; this was a great advantage to us in that material could be readily obtained throughout the winter. The water in the springs is very cold during the summer as well as in the winter months and the larvæ, being accustomed to very cold water, would not live, during the summer, in aquaria kept in the laboratory or out of doors. We found it advisable to carry on our experiments during cold weather, at which time it was easy to keep the aquaria in cool places, bringing them into the laboratory only when our specimens were examined. In the autumn and in the spring, just before or after freezing began or ceased, we found the most convenient times for our work, as at these periods of the year the aquaria could be kept on a ledge outside of the laboratory window.

The cases of the larvæ of *Platyphylax designatus* are constructed, with few exceptions, from the sand which covers the bottom of the springs in which they live. Irregularities in the size of the sand grains used are sometimes observed, but there

[1] The identification of the species was made by Mr. C. Betten.

is, in general, a regular arrangement; the posterior, oldest, part of the case is made entirely of small grains, the anterior, newest, part of the shell of much larger and more irregular grains; between the two ends there is a gradual increase in the size of the sand grains used. As the larvæ increase in size the shell is made wider and larger grains are used in its construction; after building is completed, or nearly so, there are often two or three very large pieces placed near the anterior end. When the larvæ begin to prepare for pupation nearly all the pieces added are of greater size than any of the others, and, finally, when the case is closed, the anterior fourth or third is nearly covered with these large grains, which are so marked and constant that by their presence one can easily tell a larval from a pupal case. Often just before pupation a larva would close the posterior end of its case by the addition of a single large sand grain over the opening at this end. After closing the shell for pupation a small opening was always left at the anterior end. This was found between two of the large sand grains, the space between which was filled with a layer of the secretion from the spinning glands, and in this the opening was found.

Two different kinds of plant seeds were sometimes used in the construction of the cases and these, with the rare use of pieces of snail shells, composed with the sand grains, the materials of construction. In many instances when the seeds had been used in building a case but one or two of them were used; cases were, however, often found in which were a dozen or more of the seeds and often the two kinds were found in the same case. We had several larvæ with these cases living for a few days in the laboratory where the water remained warm and this sometimes resulted in the germination of the seeds. When this happened the larvæ presented a curious appearance, their cases having a few young plants, one quarter to one half an inch in length, growing on them.

The experiments we made were upon the construction of new cases by larvæ from which the original cases had been removed, and upon the repair of cases after certain parts had been cut out. To facilitate the work and make it possible for us to tell exactly how much new shell had been added, we placed in our aquaria,

not the brownish sand from the springs in which the larvæ lived, but crushed red sandstone. When a larva rebuilt the part of the shell we had removed it was easy to see just how much new material had been added.

The construction of a new case is easily observed by removing larvæ from their cases and placing them in aquaria at the bottom of which is some sand. The larvæ appear at first much distressed and wander around in the aquaria attacking each other, if a number are in the same dish, but never, so far as we have observed, injuring one another. From the fact that the caseless larvæ always attack each other it is much better to place but a single one in an aquarium. Many will remain for one or two days without attempting the construction of a new case while others will begin building within an hour, or in a few instances, in even less time. When a larva begins the construction of a new case it first, with its mandibles, gathers a few of the larger sand grains and cements them together with the secretion from the spinning glands. This done, the larva gathers other grains from a distance carrying them in its mandibles to the pile already formed, and, as each is brought, it is cemented to the others. In this way, in the course of from two to four hours, a large pile of sand grains is made, each grain of which is cemented to the others, forming all together a loose mass nearly as large as the larva itself. It is now somewhat surprising to notice that the larva, in beginning to construct its shell, does not, apparently, use this pile at all but begins its case at one side and adjacent to it, and there, from smaller grains than those in the pile, the new case is built. The first process in the actual construction we did not see but the larva soon has a narrow band of case around its body and to this, at the anterior end, new grains are continually added. As the new case increases in length, the diameter is slightly enlarged although the new cases do not show as much difference in width at the two ends as did the old shell. When the case has reached the necessary length the larva turns in it and begins to pull down the posterior margin, finally making the opening at this end smaller than the diameter of the shell. The larva again assumes its original position and finally builds a slight dorsal hood at the anterior end. During the construction

of the case the original pile of sand grains has been attached to its posterior end and may be dragged around by the larva; it is however finally cut off and remains at the bottom of the aquarium. Whether or not the construction is similar in the natural habitat of the larvæ we do not know.

Cases cut Longitudinally from End to End.

Without removing the larvæ the cases were cut with scissors from end to end and on different surfaces. It was necessary to cut the cases slowly avoiding the largest sand grains and taking care not to injure the larvæ.

1. The cases of three larvæ were cut, one dorsally, one ventrally, and the third along the lateral surface. The following day the laterally cut one had glued the cut surfaces together in the anterior region; the other two had not been repaired.

2. The experiment was repeated with three more larvæ and at the end of twenty-four hours all had glued, anteriorly, the cut edges together for one third the distance.

3. The case was cut ventrally in one larva and on the following day it had been repaired the same as above.

4. A larva with case cut dorsally gave the same result.

5. On the twenty-sixth of the month a case was cut dorsally and the larva removed from it; the following day it had returned to its case and cemented the edges at the anterior end for about one quarter of the distance. Twenty-eighth, the larva had cut out a notch at the anterior end, at terminus of original cut, and built in with new sand. Twenty-ninth, had added a few sand grains to posterior edge of shell. First of following month, had added a band, two grains wide, at the anterior margin.

6. On the twenty-fifth a case was cut dorsally which by the following day had been repaired at the anterior end for about one third its length. Twenty-eighth, case cut again in the same plate. Twenty-ninth, no repair. Thirtieth, edges glued a little at anterior end and two rows of sand grains added to this margin. Thirty-first, same. First, cut again. Second, glued anterior third of distance and added from four to five more rows of sand at this end; cut again in same place. Third, again glued at

anterior end and more sand added, making a total of 2.5 mm. Fourth, cut again. Fifth, had cemented at anterior part; cut again. Sixth, cemented as before; cut again. Seventh, eighth, ninth and tenth, cementing and cutting repeated each day. Eleventh, cut edges at anterior end cemented as before and a little more new sand added to this end.

7. Six cases were cut, two dorsally, two ventrally, and two laterally. The time during which these experiments were carried on was at least two weeks in each instance, giving sufficient time for full action on the part of each larva.

Of the two cut dorsally one ignored the cut entirely but built on a ring of new sand at the anterior end after eight days had elapsed. The other at once cemented the cut edges for a distance of 2 mm. at the anterior end, then, for a period of nine days, did nothing further. Repetition of the cutting had no other effect than to cause, within a short time, the larva to glue the edges for a short distance at the anterior end.

The two cut ventrally took much more notice of the injury to the case than the preceding. One of these closed the cut half way down from the anterior end and at the end of two days had completely glued the cut edges together. Repeated cutting caused, with one exception, a partial repair within twenty-four hours. After five such repetitions an additional day was allowed for repair, at the end of which time, the cut edges were completely glued. The second had at the end of twenty-four hours cemented the cut at the anterior end for a distance of 2 mm.; then for eight days it did no further repairing. The cut was then reopened and at the end of twenty-four hours was again partially closed. The next day the larva had turned in its case and was working at the posterior end and on the following day had completely cemented the cut edges.

The first of the two laterally cut specimens would always close the cut for about one third the distance at the anterior end, and once, when allowed four days, completely repaired the injury. Twice a new ring was added at the anterior end instead of the usual repairing. The second of these larvæ did nothing for four days. It then closed the cut for a distance of 2 mm. at the anterior end and for four additional days made no further repair.

The cut was now well opened daily for seven days. On each of the first two days a distance of 1 mm. at the anterior end was repaired, on the third and on the fourth days 2 mm., and on the fifth and sixth days a distance of 4 mm. was repaired. The repairing on the sixth day was very poorly and loosely done and, no repair being made on the next, the seventh day, the experiment was abandoned.

The cutting of the cases from end to end causes no inconvenience to the larva and no exposure of its body. In all examples cut it was difficult to see, without a fairly close examination, that a cut had been made; the firmness of the case causes the cut edges to either touch along their entire distance or, in many instances, to slightly overlap. The repair was always begun at the anterior end, the larvæ paying but slight attention to the opposite end although, in a few cases, this was also repaired and it may be, that if the cut cases had been in every instance left unmolested for several days the ultimate result would, in all experiments, have been a completely repaired case. The distance of the repair at the anterior end represents the distance which can be readily reached by the larva without turning in its case.

Notches cut in Case at Anterior End.

These notches were cut in from the anterior margin of the case and on its different surfaces; the cuts were in general equal in depth to one fourth or one fifth the length of the shell. While not always of the same size and shape the piece removed was generally very nearly 3 mm. in length and 2 mm. in width at its base, the base of the triangular piece cut out being always along the anterior margin of the case.

1. Twenty-ninth, lateral notch cut; in two days this was half filled with new sand grains; the next six days no change. In thirteen days the notch had been completely filled in and a few grains added to the anterior edge.

2. Dorsal notch cut, was completely repaired in two days.

3. Dorsal notch cut and partially repaired by following day; in building a small opening was left by the larva at the apex of the notch and this was never repaired. In two days the anterior margin was built even to rest of case.

4. Dorsal notch cut in case and it was completely filled the following day; this was repeated seven more times and each time the notch was filled in twenty-four hours; the ninth time the repair took two days. The larvæ now added a narrow band to the anterior edge of the case; this was removed and rebuilt three times in as many days.

5. Dorsal notch cut and repaired seven times daily with one exception, in which the period of repair extended for two days.

6. Ventral notch cut six times and repaired five times, each at end of twenty-four hours, and once after interval of two days.

7. Two cases, in each of which a dorsal notch was cut, were repaired by the following day.

8. Dorsal notch cut but not repaired for three days.

9. Lateral notch cut and repaired in three days.

10. Two cases notched, one dorsal and one ventral, were both repaired in twenty-four hours, but in each instance a small opening was left at apex of notch which was never repaired.

Any portion of the case which has been removed from the anterior part, provided the piece removed includes part of the margin, was repaired in a short time. If the piece removed was taken from the shell at some place away from the margin, repair is neglected and the opening allowed to remain. In two of the experiments recorded it will be noted that in filling in the notch a small part was left open and this was never repaired. Some larvæ not recorded had holes cut in their shells and after a lapse of several days the openings were still unrepaired. A larva can easily fill in a notch 2 × 3 mm. in twenty-four hours.

Case Cut Transversely into Two Pieces.

In the following experiments the cases were cut transversely into two pieces, which were as nearly equal as we could make them without an actual measurement. The larvæ were then replaced in the aquaria with both pieces of the case still on their bodies.

1. On the first of the month a case was cut and one piece, 6 mm. in length removed. Second, at 8 a. m., the new part added to old piece left on the larva was nearly equal to the part removed, and at 4:30 p. m. it was of the same length. Third,

the new part was now 8 mm. long, or 2 mm. longer than the part removed, and it was also somewhat wider. Fourth, new piece 10 mm. in length. Seventh, larva had added 2 mm. more and closed the shell for pupation.

2. Fourteenth, case 11 mm. in length cut and both pieces left on larva. Fifteenth, the larva had thrown off the posterior piece and built 2.5 mm. to anterior end of piece (anterior) which it had retained; total length 7 mm. Sixteenth, length of shell had been increased to 11 mm., the original length.

3. Fourteenth, case 10 mm. long was cut and both pieces left on the larva. Fifteenth, the posterior piece had been thrown off and 3.5 mm. built on to anterior end of remaining piece. Sixteenth, enough had been added to make entire length of case 10 mm.; equal to the original.

4. Second, a case 11 mm. long was cut and on the following day the posterior half had been thrown off and 4.5 mm. added to anterior end of the piece retained by the larva. During the day the larva reversed itself in the case and turned in the posterior edge; total length 9 mm. Fourth, removed the new anterior part which the larva had built. Fifth, had again added 4.5 mm. to old part of case. Eleventh, abandoned old shell and built a new one which, by the fourteenth, was 9 mm. long.

5. Second, a shell 9 mm. in length was cut and by the following day enough had been added to the anterior piece of the old case to make it 10 mm. long. Fourth, cut between old (posterior) and new (anterior) parts. Fifth, had thrown off the old (posterior) piece and added 3 mm. to other part. Seventh, case had total length of 9 mm. Fourteenth, total length 10 mm.

6. Fourteenth, cut a shell 10 mm. long; the same day the larva threw off the posterior piece and added 2 mm. to the anterior end of the piece. Sixteenth, length of new part only 3 mm. and on the next day had increased to 3.5 mm.; total length of case 9 mm.

7. Thirty-first, case 11 mm. in length was cut and on the following day the posterior piece had been thrown off and 4.5 mm. added to anterior end of the piece retained by the larva. Third, case was cut between the new and the old parts. Fourth, old part (posterior piece) had been thrown off and enough added to

other piece to make total length of shell 10 mm. Sixth, the posterior end was turned, total length of shell 10.5 mm.

8. Second, shell 9 mm. long was cut: on the following day the posterior piece had been thrown off and 3 mm. added to anterior end of remaining part. Fourth, posterior end had been turned; 3 mm. of the new shell removed. Fifth, 1.5 mm. added. Seventh, total length of shell now 7 mm.; following day the larva was dead.

9. A shell 12 mm. long was cut and on the following day the two pieces were glued together and a few new sand grains added to the anterior end.

10. A shell 12 mm. in length was cut and on the following day the posterior part had been thrown off and 5 mm. added to anterior end of remaining part. After an interval of one more day 7.5 mm. of new shell had been added; total length 12.5 mm.

11. Fourteenth, shell 12 mm. long cut. Fifteenth, posterior part had been thrown off and 2 mm. added to anterior end of remaining part. Sixteenth, 5 mm. more added. Seventeenth, 0.5 mm. added: total length 9.5 mm.

12. Thirty-first, case 11 mm. long was cut. First, posterior part thrown off and 4.5 mm. added to anterior end of other part. Second, no change. Third, cut again at boundary of old and new parts. Fourth, the posterior piece again thrown off and enough added to make total length of case 10 mm. Eighth, posterior end turned, total length of case 10.5 mm.

In but one of these experiments did the larva glue the two cut margins together and when this had been done the case was nearly as good as before cutting, except its greater flexibility and a slight lack of strength. In every other experiment the larvæ threw off one of the pieces, always the posterior, and built on to the anterior margin of the remaining (anterior) piece. The construction of the new part of the case was rapid, averaging nearly 4 mm. the first twenty-four hours; to this more material was added until the case had entirely or nearly reached the original length. One half of the case is not long enough to entirely conceal the body of the larva and the first work is to increase the length of the case sufficiently to do so, after which what we might call the finishing touches, *i. e.*, turning in the posterior margin and building of a hood at the anterior end are finished.

REMOVAL OF PART, OR WHOLE, OF POSTERIOR END.

1. Thirty-first, cut off the posterior end of a case and by the following day the larva had turned in the edge; cut again. Third, had slightly turned the edge. Fourth, cut 2.5 mm. from posterior end. Fifth, had added 5 mm. to anterior end. Eighth, 2.5 mm. more added. Tenth, posterior edge turned.

2. Small piece cut from the posterior end and by following day the edge had been turned and four grains of sand added at this end; case but slightly smaller than before cutting. Following day the larva was dead.

3. Second, cut piece 4.5 mm. long from posterior end of a case which was 11.5 mm. in length. Third, added 3 mm. to anterior end. Fourth. 1 mm. more had been added. Seventh, 2.5 mm. more added and anterior end closed. Eighth, both ends of case closed and it was glued to a leaf for pupation.

4. Second, cut piece 3.5 mm. from posterior end of a case. Third, 1.5 mm. had been added to anterior end. Fourth, 0.5 mm. more added. Tenth, new part now 3 mm. in length, posterior end not yet turned.

5. Ninth, cut 4 mm. from posterior end of a case and by the following day 3.5 mm. had been added to the anterior end. Fourteenth, a few sand grains added to the posterior end; case closed for pupation.

These few experiments on the posterior end show that the larvæ are loath to work at this end of the case and the additions to the shell were made at the anterior end. As the cases are normally turned in at the posterior end most injuries to this end will result in the larvæ ultimately reversing themselves in the case to re-turn the margin. We watched the larva turn from a reversed to a normal position, the whole process occupying about four minutes. At first the posterior end of the body is protruded from the anterior opening; the head is then bent forward and soon appears at the opening. Next, by a seemingly very strenuous effort, the body is withdrawn into the case and the larva assumes its normal position. During the process the second pair of legs are thrown up into a position dorsal to the thorax and pointing backward. The larva takes a short rest during the reversing process. That the effort is an extremely

hard one is evinced by the fact that we have, during our experiments, found larvæ which have been "stuck" in turning and died without being able to completely turn.

Notches Cut at the Posterior End.

1. Four cases were cut, two dorsal and two ventral. The two ventrally and one dorsally notched case were closed the following day, but without the use of sand, the secretion from the spinning glands being used and the cut edges partly drawn together. The fourth specimen did nothing on the first two days; the third day, and, thereafter each day for five days, new grains were added to the anterior end until a new part 4 mm. in length had been built.

Two experiments were made by cutting, day after day, a small piece from the posterior end of the case, thus forcing the larva to add continually to its case if it desired to keep it long enough for its body. It was found that either daily or every two or three days a small portion would be added; if daily, a smaller amount than if the larva waited one or two days before making the repair. No tendency to exhaustion of the silk was noticeable during the three weeks or more that the experiments lasted.

No. 1 built a total length of new case 17.5 mm. in twenty-one days; average 0.83 mm. daily.

No. 2 built a total length of 19.5 mm. in twenty-three days; average 0.84 mm. daily.

With several larvæ the experiment was tried of driving them out of their cases and then placing both larva and case in the same dish to ascertain if they would return to old case. Two larvæ were placed in each dish, a large and a small one, to see whether a larva would occupy a case built by another; with this arrangement there could of course be but one change, that of the smaller larva into the case of the larger. When new cases were constructed these were destroyed leaving only the original ones.

1. Did not return to old case. Built a total length of 32 mm. of new case in the first four days. Rested a day and then added 6 mm. more in two following days. Total length of new case built in seven days 38 mm. Average 5.42 mm. per day.

2. Reëntered case at the anterior end, the regular method, but in reversing stuck fast and died.

3. Returned to old case five times out of seven trials. Built 12.5 mm. in eleven days. Average 1.1 mm. per day.

4. Out of eight trials returned to its old case twice and to that of larger larva once. Built five new cases in thirteen days with a total length of 42 mm. Average 3.23 mm. per day.

5. Did not return to its old case. Out of eight trials lasting thirteen days a new case was built each time but one. Daily average 4 mm.

6. In six trials built a new case each time then occupied case of larger larva twice, the last time adding a new part of smaller diameter to the shell. In twelve days built 42 mm. of new case. Average 3.5 mm. per day.

7. Out of six trials returned to old case five times, building only 5 mm. of new material. Went without case for two days during which time the old case was occupied by another larva. Daily average of new case construction only 0.38 mm.

8. In eight trials a larva returned once to its own case, three times to that of a larger larva, and four times built new cases; 23 mm. of new cases were built in fourteen days. Daily average 1.64 mm.

9. Did not return at all to old case but built, in fourteen days, a total of 65 mm. Average daily construction 4.64 mm.

10. November 7, took a larva out of its case and it immediately crawled in again at the anterior end. Eighth, had assumed proper position in case and added new ring of sand grains at anterior end. Removed again from case but it reëntered as before. On the ninth, tenth and eleventh, the larva was removed from its case but each time time reëntered and added a little new material to the anterior end, 3 mm. in all. Twelfth, removed from case but did not again return and not until the sixteenth was a new case constructed, at which time it was 10 mm. long. Seventeenth, case 15 mm. in length. Eighteenth, case 16.5 mm. long; removed larva from it. Nineteenth, had constructed a new case which was 11 mm. long. Twenty-first, new case had 2 mm. more added; removed the larva. Twenty-second, another new case 7 mm. long had been built; again removed the larva.

Twenty-third, the larva had returned to its original case. During the six days of its greatest activity in building the larva had constructed 36.5 mm. of new case, a daily average of 6.08 mm. The daily average for the entire experiment was 2.25 mm.

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